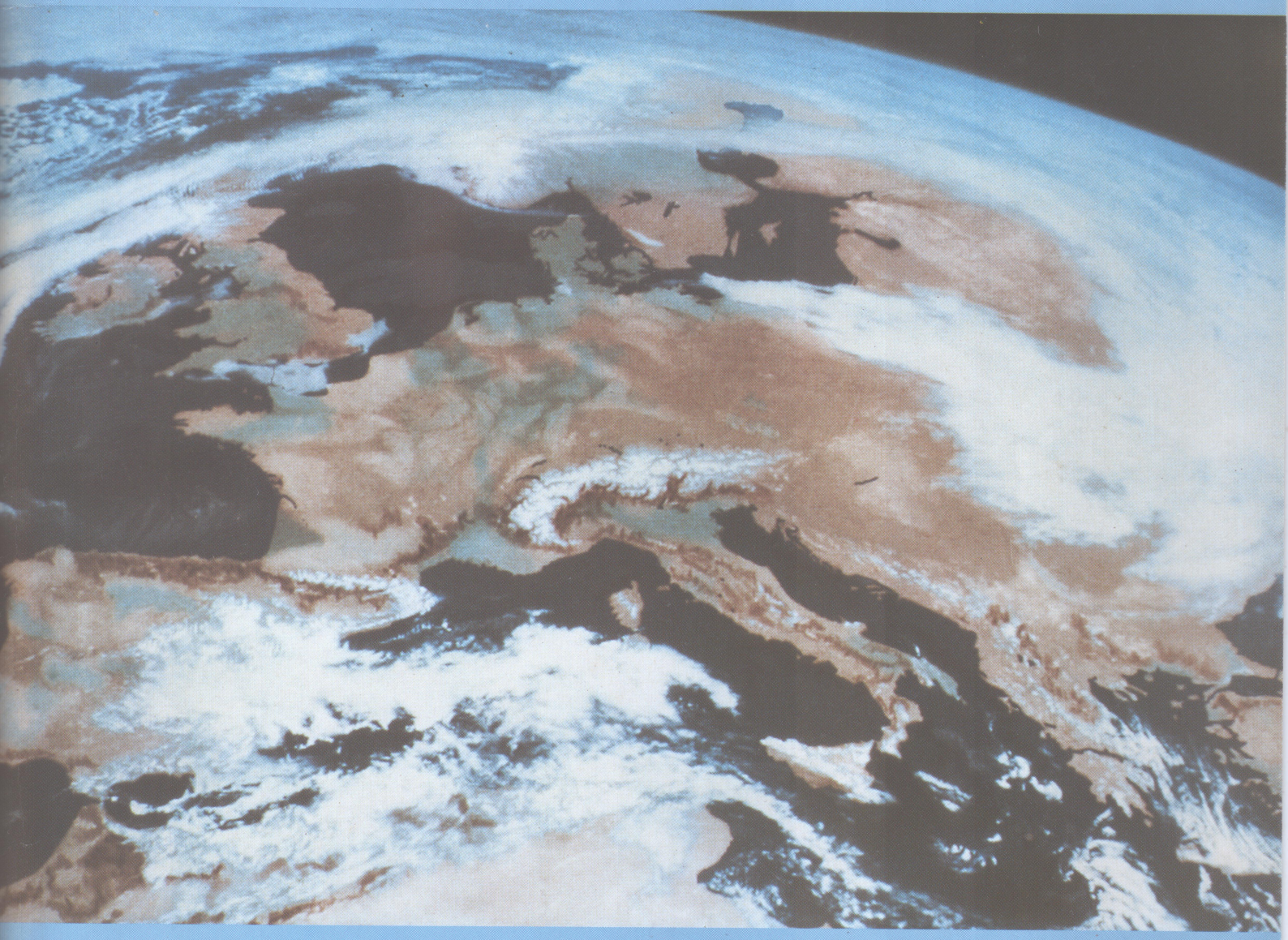
SWEDEN IN SPACE



Swedish National Space Board

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Professor Kerstin Fredga,
Chairman and Director
General of the SNSB

FOREWORD

Space has always fascinated man; and the understanding of its origins and its exploration are among our greatest remaining intellectual and physical challenges.

It has always been a rich field for scientific study and application. Navigation by the stars is one early example of the utilization of space for exploration of the Earth.

Telecommunication and earth-observation satellites, space-based telescopes and laboratories and manned space vehicles are the successors of those early expressions of man's quest for exploring the surrounding world to extend the limits of knowledge and conception.

The peaceful exploration of space gives us perspective in our striving to define our role on Earth and in the Universe; it is an essential part of our culture.

This booklet is intended to give a brief orientation of the Swedish space programme and of our scientific and technological capability to contribute to the overall knowledge on space and its potential.

June 1990
Kerstin Fredga

SWEDEN IN SPACE

1. INTRODUCTION

Space activities are a field of growing interest in an increasing number of countries in the world.

The awareness of the fact that space technology has a crucial and permanent role to play in areas such as basic scientific research, communications, the inventory of natural resources, environmental control, mapping, peace surveillance, research and manufacturing in conditions of microgravity has been a decisive factor when appropriations to space activities have been decided upon.

Other decisive factors for investments in space in Sweden are increased industrial competence and competitiveness as well as regional industrial development policy.

It is of vital interest for Sweden to gain, retain and develop a national competence in space technology. This competence strengthens ability to judge independently and makes it possible to capitalize the results of the development of space technology for research and application. It also strengthens the ability to uphold and assert a national position in international competition.

Space activities are international in character. Space projects are often of such a magnitude that their realization presupposes the pooling of intellectual and financial resources from several countries. Sweden's participation in international and, more specifically, European space co-operation is one of the conditions for development of space-based activities in Sweden.

The experience gained over time of how the ratio between national and international activities influences the total result, indicates that a balance between national and international activities is necessary in order to obtain optimum results. A strong national programme is thus a prerequisite for a fruitful cooperation with other countries within and outside Europe.

The intentions behind the planning of the Swedish space programme are to safeguard and develop further those areas where Swedish space competence is very high. Key areas are magnetospheric and ionospheric research, remote sensing and specialized industrial competence.

2. NATIONAL ORGANIZATION OF SPACE ACTIVITIES

Swedish National Space Board

The Swedish National Space Board (SNSB), under the Ministry of Industry, is the central governmental agency responsible for national and international space activities in Sweden including all aspects of remote sensing. For the research programme the Board receives funds from the Ministry of Education and Cultural Affairs. Parliament, the Telecommunications Administration, the National Board for Technical Development, as well as industry and the scientific community, are represented on the Board.

The responsibilities of the Board include:

— initiating research, development and other activities connected with the Swedish space and remote sensing programme;

— co-ordination of Swedish activities within the fields of space technology and research as well as remote sensing;

— distribution of government appropriations for Swedish space activities;

— authorization and supervision of space activities in accordance with space law;

— maintaining contacts with international organizations and institutions operating within the field of space activities and remote sensing.

The Board is responsible for the planning and the coordination of Sweden's participation in the programmes of the European Space Agency (ESA).

The Board has advisory committees for science (incl. microgravity), remote sensing and industrial policy.

The technical implementation of the national programme is mainly contracted by the Board to the state-owned Swedish Space Corporation.

Swedish Space Corporation

The principal responsibilities of the Swedish Space Corporation (SSC) are:

— the technical implementation of the Swedish space and remote sensing programmes;

— to conceive, specify, and procure satellites for applications and space science research including overall project responsibility for the satellites;

— to operate the Esrange sounding rocket range and satellite ground stations;

— to perform systems management and engineering for complex high technology programmes;

— to receive image data from remote sensing satellites at Esrange. To process and analyze all types of images for different applications and customers all over the world;

— to develop and supply operational remote sensing systems for maritime surveillance and environmental control.

The Swedish Space Corporation (see Annex I) has two establishments, one at Esrange, Kiruna, and the other in Stockholm, which is also the main office.

Organization and inter-relations of Swedish space activities

The organization and inter-relations of Swedish space activities is illustrated in Figure 1.

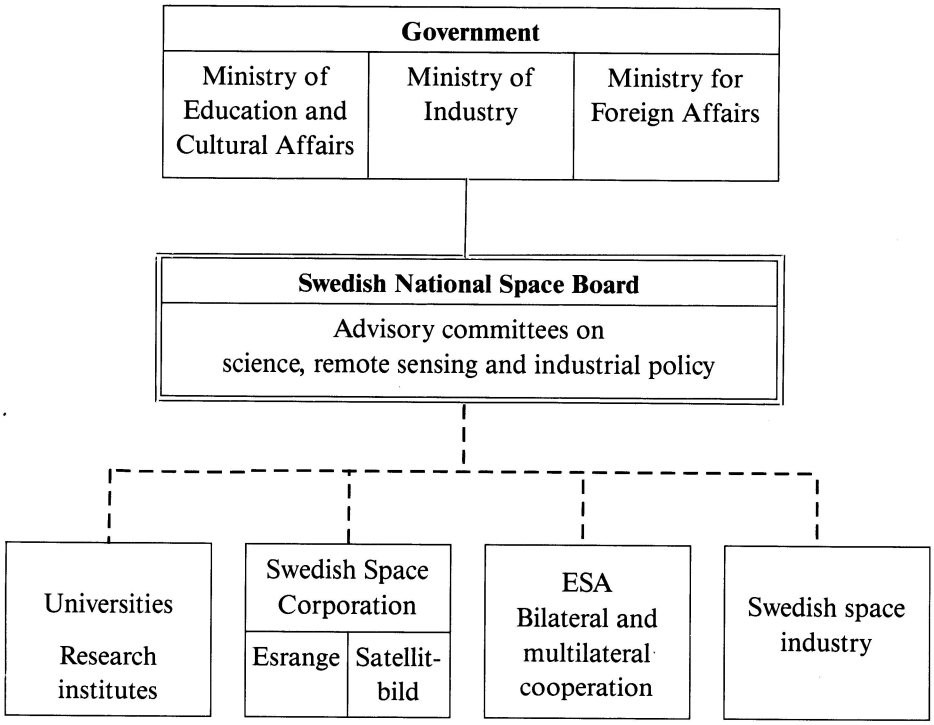


Figure 1. Organization and inter-relations

Note:
Operational space activities fall within the purview of the users. Thus the Ministry of Transport and Communication is responsible for the Swedish participation in organizations such as EUTELSAT, INMARSAT, INTELSAT and EUMETSAT.

The Ministry for Foreign Affairs is responsible for i.a. Swedish participation in the UN Committee on the Peaceful Uses of Outer Space.

3. PROGRAMME STRUCTURE AND BUDGET

The publicly funded space activities in Sweden are carried out both on national and international levels. In practice, the national and international activities are highly inter-dependent. Therefore, a balanced programme is needed to obtain optimum results from both national and international investments.

Swedish space activities are thus carried out in two main programmes, the national programme and the international programme.

National programme

The *space research* programme comprises the publicly financed basic research activities which use sounding rockets, balloons and satellites for their experiments. The main areas of the programme are classical space research and research in microgravity.

The *remote sensing* programme comprises research and development activities pertaining to the collection, evaluation and processing of data of the earth and atmosphere by means of space and airborne instruments as well as of ground based equipment.

The *industrial development* programme aims at developing technical know-how in the space field in order to promote industrial competitiveness and to introduce advanced technology on the world market.

International programme

The main part of the activities of SNSB is performed in international cooperation within the European Space Agency (ESA) where Sweden is one of the founding members.

Sweden participates in the mandatory basic and science programmes of ESA with a contribution rate of 3,5% (1990), which, in accordance with the rules in force for the mandatory programme, corresponds to the Swedish GNI .

Sweden participates in the optional space applications programmes of ESA with contribution rates based on the expected industrial return and applications potential in each programme. Sweden participates in the programmes pertaining to earth observation, space transportation, telecommunication, space station and platforms and microgravity.

Sweden's share of the optional programmes is about 1,9% and about 2,3% of both mandatory and optional programmes.

Sweden's financial contribution to ESA comes, to a large extent, back to the country in the form of industrial development contracts and the long-term build-up of knowledge and know-how. Participation in European industrial cooperation also results in acces to overall achievements in the field of high technology.

The returns by way of industrial contracts have been estimated to be equivalent to about ⅔ of the financial contributions that Sweden has paid to ESRO and ESA since the 60's. Through these contracts the Swedish space industry — primarily Saab Space AB, Ericsson Radar Electronics AB, and Volvo Flygmotor AB — has been able to develop a very high competence in fields such as spaceborne data equipment, antennas, microwave technology and rocket motor technology.

Part of the research activities at the space research range, Esrange, in Kiruna, which are carried out using sounding rockets and balloons is run as a special project within ESA. Participating states in addition to Sweden are the Federal Republic of Germany, France, Switzerland and Norway.

Sweden has also an extensive bilateral co-operation. Bilateral scientific co-operation between Sweden and the US is carried out under an agreement with NASA.

Similarly, scientific co-operation is carried out with the USSR under a Memorandum of Understanding with the Intercosmos Council of the Soviet Academy of Sciences.

Bilateral co-operation work on space science and applications, primarily the SPOT-programme, is carried out between Sweden and France under an agreement with Centre National d'Etudes Spatiales, CNES.

Sweden and the Federal Republic of Germany are cooperating on i.a. the scientific satellite Freja and in the Sänger programme.

Memoranda of Understanding have been concluded as a basis for co-operation with Austria, Canada, India and the People's Republic of China. Sweden is also engaged in other bilateral co-operative projects with Denmark, Finland, Italy, Japan, the Netherlands, Norway, Switzerland and the United Kingdom.

Budget

The structure of the Swedish space programme is graphically presented in Figure 2. The total budget for the publicly funded space programme amounted to 402 MSEK for the fiscal year 1989/90. This represents a share of 1,0 per mill of the national budget and 0,38 per mill of the GNI.

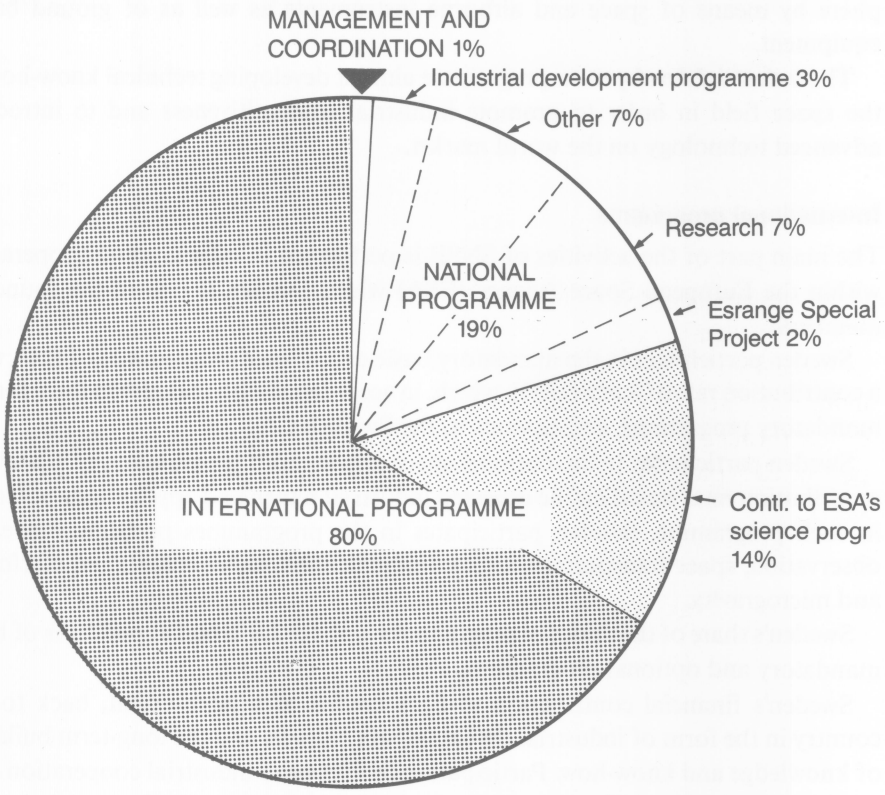


Figure 2: The space programme structure (based on FY 1989/90, Annex IV)

International programme 80%

(Contribution to the scientific programme of ESA 14%, contribution to the basic and applications programmes of ESA, incl SPOT cooperation 66%.)

National programme 19%

(Industrial development programme 3%, space research 7%, Esrange Special Project 2%, other activities 7%)

Management and Coordination 1%

The development of funding over time for the Swedish space programme is illustrated in Figure 3.

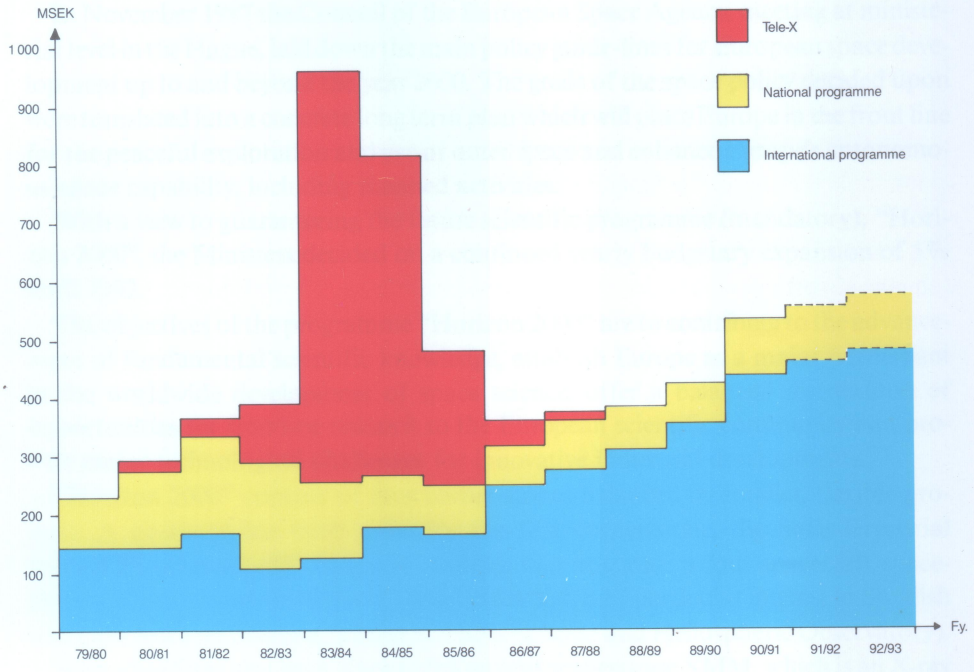


Figure 3: The Swedish space programme: development of public funding (in 1988 year's economic conditions).

Successive political decisions during the 60's and early 70's led to the development of a Swedish space programme and the establishment in 1972 of the SNSB and SSC. In 1979 the decision was taken to substantially increase the funds over some years for industrial development in order to increase the competence of the Swedish space industry through the establishment of a national technology programme. The main part of that programme was the telecommunications satellite Tele-X (launched in 1989).

4. PROGRAMMES AND PRIORITIES

4.1 Science (incl microgravity)

From the very beginning of space history basic research has played a crucial role. General, basic physics research prepared the ground for today's rocket and space technology. It also became the task of scientists to investigate, to map out and to master the specific environment that satellites, space craft and man encounter in space.

The aim of the research carried out today by means of space technology is, generally speaking, to obtain an in-depth understanding of our surrounding environment, from near Earth to the Universe. Space research is thus greatly contributing to the ultimate goal of all basic research, namely to enable man to orientate himself in time and space, to get perspectives on the existence and to understand the complexity of a greater whole.

Space research encompasses large areas of modern physics such as astrononomy, plasma physics, atmospheric physics, material physics and biophysics.

The long term effects of space research for man's conception of the world is an extremely important aspect of space activities. The difficulties to gauge and assess such long term effects in economic terms must not lead to basic research being neglected.

Despite being a small country, Sweden has kept pace with other industrialized countries which are involved in international co-operation and has also been able to contribute substantially to fundamental space research. This has been made possible by a concentration of resources to those areas where Sweden has excellent scientific competence and where our geographical position presents specific advantages. This is the case, for example, in space plasma physics, where Sweden has a long research tradition and outstanding scientists and where the location of the space research range, Esrange, in the northern auroral zone (latitude 68° N) gives a clear advantage.

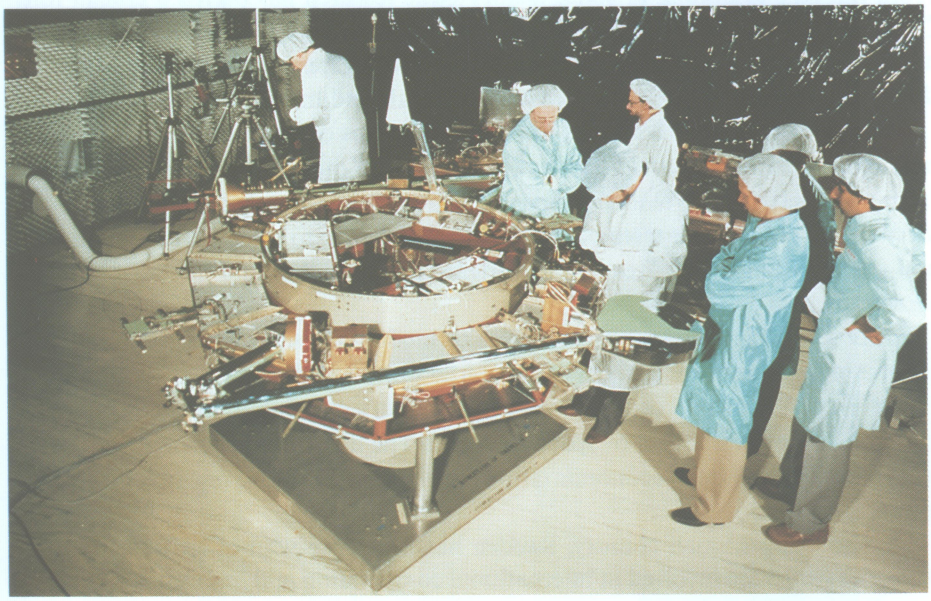
Esrange and the scientific environment which has developed around it constitutes an invaluable resource. Scientists from all over the world gather here to work on joint projects. The Swedish space research programme is, to a large extent, being carried out in international co-operation. This implies a fruitful exchange of ideas in the very front line of basic research. It also implies that Swedish space research is the subject of a continuous assessment and quality control in an international context. The Swedish scientific satellite Viking, with control and data reception at Esrange, as well as the launching of sounding rockets and balloons have been the backbone of the Swedish national space research programme. Because of its position at a high northern latitude, Esrange is particularly well suited to receive data from and to track and control satellites in polar orbits. Facilities for these activities are now established and are being further developed. Similar possiblities are being created for launching high altitude sounding rockets (to about 1 000 km). This will give extended opportunities for both classical space research and research in microgravity. Also the possibilities of launching balloons have been expanded.

In a balanced national space research programme — balanced with respect to Sweden's international commitment as well as to the needs of the various research disciplines — continuous access to satellites is judged to be of the utmost importance. Research activities using sounding rockets and balloons are initiated and carried out by the research teams within the areas of plasma physics, astronomy, atmospheric chemistry and material sciences. Projects using sounding rockets and balloons and which have relatively short turn-rounds also play a role in the training of research students at the universities.

An overview of the Swedish research teams is given in Annex II.

Space Plasma Physics Research

Space plasma physics is an area with a long scientific tradition in Sweden and an area where scientific results in the ultimate front line of research can be obtained with relatively small satellites. The reason for this is that the basic research is presently concentrated on specific physical processes in the near space. Dedicated instruments and orbits are however necessary. One example of such a scientific satellite is the very successful Viking satellite which became Sweden's first satellite.



Integration of the Viking satellite. (Photo Saab Space AB)

Viking was launched by the Ariane launcher from Kourou in 1986. After 444 days Viking stopped functioning due to gradually decreasing power generation. The life time which was originally designed for eight months, was thus nearly doubled.

The scientific task of the Viking satellite was to study the ionospheric and magnetospheric phenomena at high geomagnetic latitudes in the altitude region up to about two Earth radii. Simultaneous measurements were made of electric and magnetic fields, particle distributions, plasma composition and waves as well as imaging in the ultraviolet of the aurora beneath.

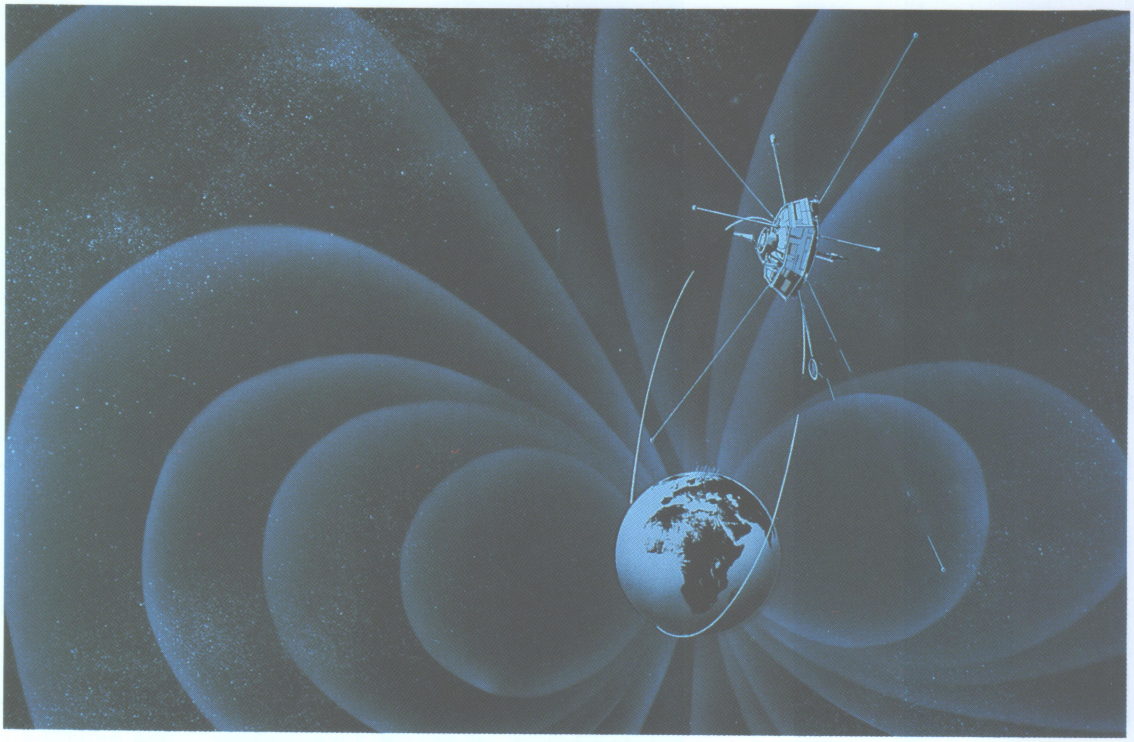
The instruments were supplied by the three Swedish magnetospheric groups and by scientific teams in Denmark, Norway, France, the Federal Republic of Germany, Canada and the United States.

Viking was operated from Esrange, where the telemetry data from the satellite were received and processed on a real time basis. Viking has yielded scientific results which go far beyond expectations. Also from an industrial point of view Viking was a success as it proved that an advanced scientific satellite does not necessarily have to be expensive.

SNSB has decided to continue this successful Viking low cost line with Freja.

In co-operation with the Federal Republic of Germany *Freja* is planned to be launched in 1992 in a lower orbit than Viking, i.e. in the lower part of the region where there is an interchange or interaction between magnetospere and ionosphere.

The satellite will weigh 230 kg in the final orbit, which will range in altitude between 650 and 1 800 km. The inclination of the orbit is 63 degrees. The scientific mission of Freja has many similarities with that of Viking. The auroral zone is thus the "mission target" and the satellite will carry energetic particle detectors, magnetic and electric field sensors and, possibly, also a UV imager. The Freja design strives to provide a substantially higher data rate than used on Viking.



Viking in its polar orbit. (Artistic impression: Nils Peterson)

Freja will be launched during a period of intensive solar activity in contrast to Viking which carried out its mission during a period of low solar activity. This will give an opportunity for interesting comparisons.

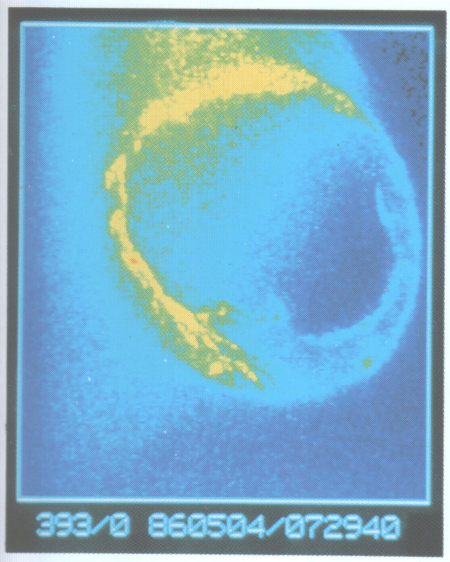
There are also preliminary plans to embark on a multisatellite project in international co-operation IMPACT (Investigation of Magnetospheric Particle Accelaration and Turbulence).

PROMICS are joint Swedish-USSR experiments onboard PROGNOZ-satellites. The first PROMICS experiments were launched 1978 and 1980. A third PROMICS-experiment is planned for launch within the Interball-concept.

The Institute of Space Physics in Kiruna participated with two hot plasma experiments (ASPERA) onboard the USSR space probes (Phobos I and II) to Mars launched in July 1988, from Baikunur. In spite of damage to the probes, the Swedish research group obtained valuable data from Phobos II during its life time. This research group will also be involved in the planned USSR project Mars -94.

The Institute of Space Physics in Kiruna is also participating in the development of a particle experiment for the ESA spacecraft Ulysses.

The three magnetospheric groups are involved in the Cluster project in the Solar Terrestrial Science Programme, the first cornerstone in ESA space science programme "Horizon 2000".



The northern auroral oval seen from above by the Viking satellite.
(Picture: University of Calgary, Canada)

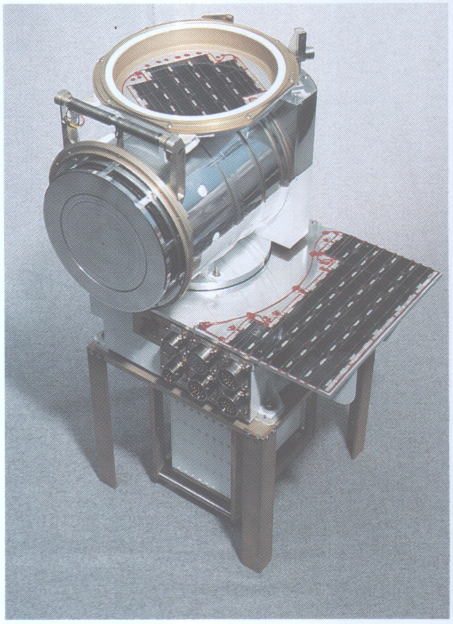
Astrophysics and atmospheric physics

The Stockholm Observatory is running a high altitude balloon experiment comprising a 30 cm stabilized IR telescope equipped with a liquid helium cooled spectrometer. The scientific aim is to make wideband observations of interstellar far-infrared emission lines. A couple of attempts have been partially successful. A second generation platform of the Pointed Infrared Observation Gondola, PIROG MK II, will be

launched. The Stockholm Observatory also takes active part in the ESA satellite project, Infrared Space Observatory (ISO), in the construction of the infrared camera. Several astronomical groups are actively involved in the satellite projects IUE, Hipparcos and Hubble Space Telescope in the fields of observation and data analysis.

The research programme in Atmospheric Physics at the Department of Meteorology, University of Stockholm is concentrated on studies of the upper atmosphere, in particular the photochemistry and transport of atomic oxygen, nitric oxides etc in the auroral zone during the arctic winter. Experimental studies are conducted mainly by means of optical measuring techniques using rockets and ground-based facilities.

A combined astronomy and aeronomy satellite mission is under study: ~~MOSES (Molecules in Outer Space and in the Earth Stratosphere).~~ ODIN



Instrument for a Swedish plasma experiment placed on board the Soviet space probe Phobos. (Picture: The Swedish Institute for Space Physics, Kiruna)

Material sciences

Technical development and experiments in microgravity by means of sounding rockets have been carried out in Sweden since 1977 when Sweden joined the German sounding rocket programme TEXUS. This co-operation has continued through the years with Swedish experiments flown in various German modules and yearly launchings of Swedish experiment modules. The Swedish sounding rocket programme MASER, which started in 1987, offers one launch per year and a slightly longer time in microgravity than the TEXUS programme. An expansion of the Swedish sounding rocket programme is under way. In cooperation with the Federal Republic of Germany sounding rockets are being developed which will offer about 15 minutes in microgravity compared with the 6 minutes possible today.

The Swedish experiments have, since the very beginning, been directed entirely towards material physics. The experiments have dealt with processes of solidification, convection, diffusion and crystallisation with the aim of i.a. gaining a deeper understanding of various transport mechanisms in a melt. Materials being studied are metals, alloys, semiconductors and metal-ceramic composites. Lately, support has also been given to activities within the field of bio-physics. Experiment modules for crystallisation of protein and for the defining of an experiment dealing with orientation and dynamics in electrical fields of the DNA-molecule are being developed.

Life sciences

For the study of bio-medical systems with short time constants (e.g lungs, heart) parabolic flights are well suited for preparatory experiments, equipment testing, and in many cases, also for fundamental research experiments.

The advent of space stations and platforms will radically improve the conditions for all space-related research by offering possibilities to conduct experiments during longer periods of microgravity.

By tradition, Sweden has played a role in life sciences. Thus there is the potential to contribute significantly to the spacerelated research as e.g. effects of microgravity on the cardio-vascular and lung function, on the balance organ and on the central nervous system, on hormonal and other mechanisms for regulation of the fluid balance as well as on the immune defence and the formation of blood.

4.2 Remote sensing

SNSB is responsible for the research and development activities within the area of remote sensing in Sweden. The funding includes financial support to research groups and to methods and technique development. In addition, financial support is given for central information activities concerning remote sensing.

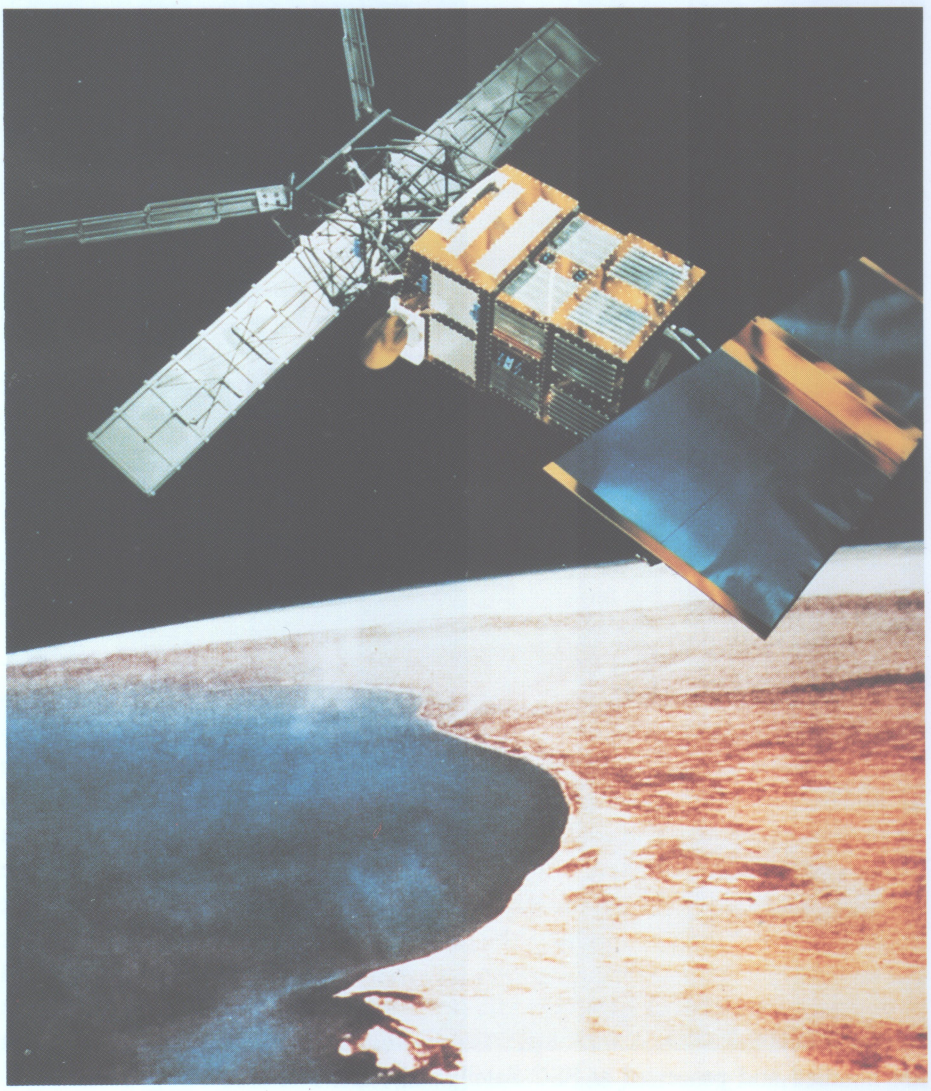
Remote sensing is an area where there has been a particularly close interaction between research, development and application. Scientists use the technique with great success and they have very actively contributed to the method development. At the same time, the field of applications is steadily expanding and forms the basis for

a growing commercial activity. Space-based remote sensing has hitherto mainly comprised optical observations for natural resource inventory and for meteorology. The European Remote Sensing Satellite (ERS-1), developed within ESA, will add to this capability through microwave observations of land, sea and ice.

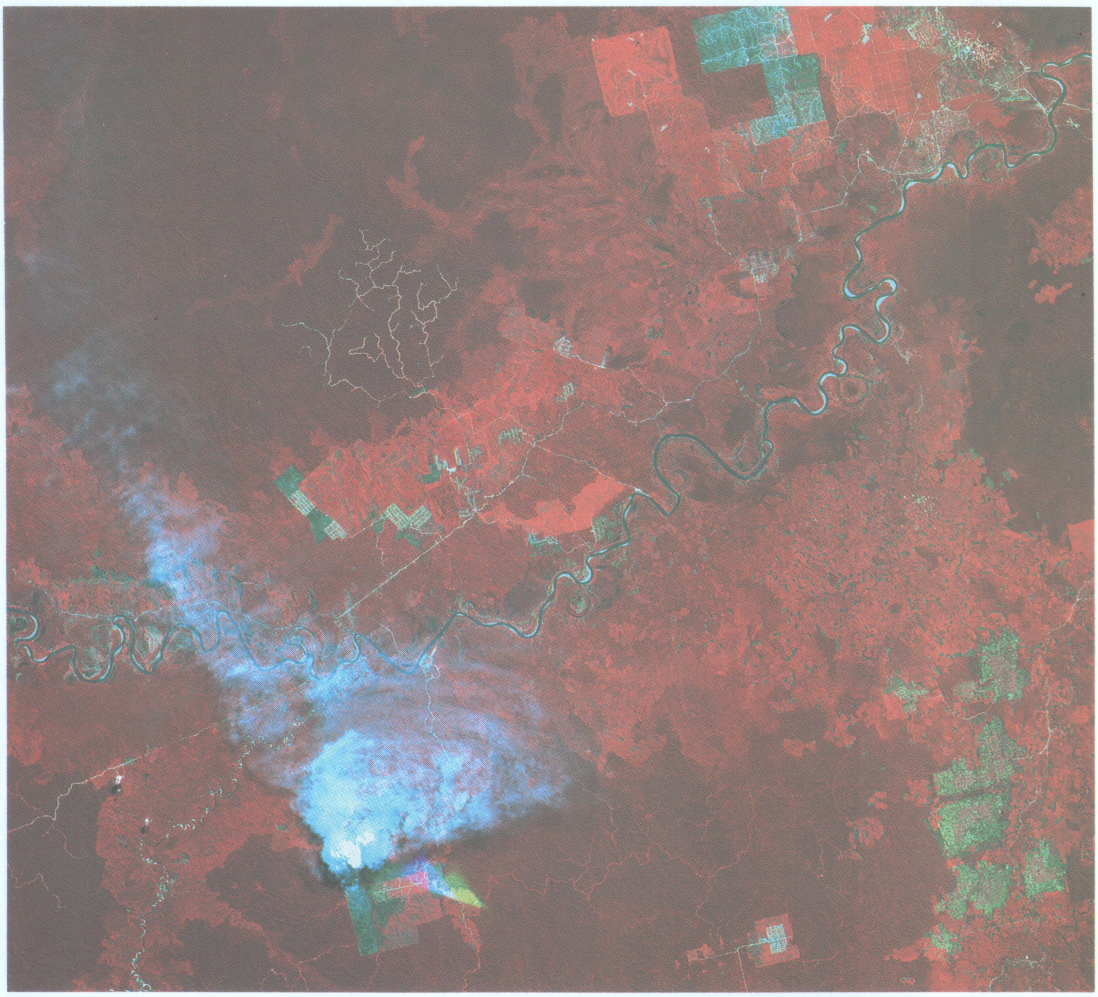
The effects of human activity on the Earth's resources, soil, water and air and the consequences for the climatological development have created a need for studying Earth as a global system of land, sea and atmosphere, linked together by hydrological and biochemical processes and energy exchange. Within the framework of "International Geosphere — Biosphere Programme: A Study of Global Change" (IGBP) — there will be vigorous action taken all over the world during the 90's in order to tackle the problems crucial to mankind. Sweden has an important role to play in the international cooperative programme.

A similar, topical, global environmental problem is that of the changes which are taking place in the composition of the atmosphere: the ongoing depletion of stratospheric ozone due to i.a. the use of freon and the continous increase in concentration of the socalled greenhouse gases linked to the production of energy from fossil fuels.

Remotely sensed data, based on optical spectroscopy and microwave radiometry from ERS-1, and future generations of SPOT and polar platforms are important links in the global information system. Ground based remote sensing in combination with measurement data from balloons, rockets and aeroplanes on local and global changes in the atmosphere can give important contributions here.



The first ESA remote sensing satellite, ERS-1. (Picture: ESA)



SPOT-image of Sumatra (Indonesia) showing the river Indragiri. The smoke comes from burn-beating. Rectilinear fields in the north-east part of the picture are large clear-felled areas. (CNES © SPOT® Satellitbild ©)

A strong competence in these areas has been built up in Sweden with the support of SNSB, and in the 90's Sweden will contribute to the global environmental programmes within the International Space Year concept "Mission to Planet Earth".

When it comes to economically viable applications the French SPOT-satellite, in which Sweden has a share, marks a break-through. SPOT 1, launched in 1986, and its successor SPOT 2, which was launched in 1990, give images of the ground with a resolution of 10 metres, in the pancromatic mode and 20 metres in the multi-spectral mode.

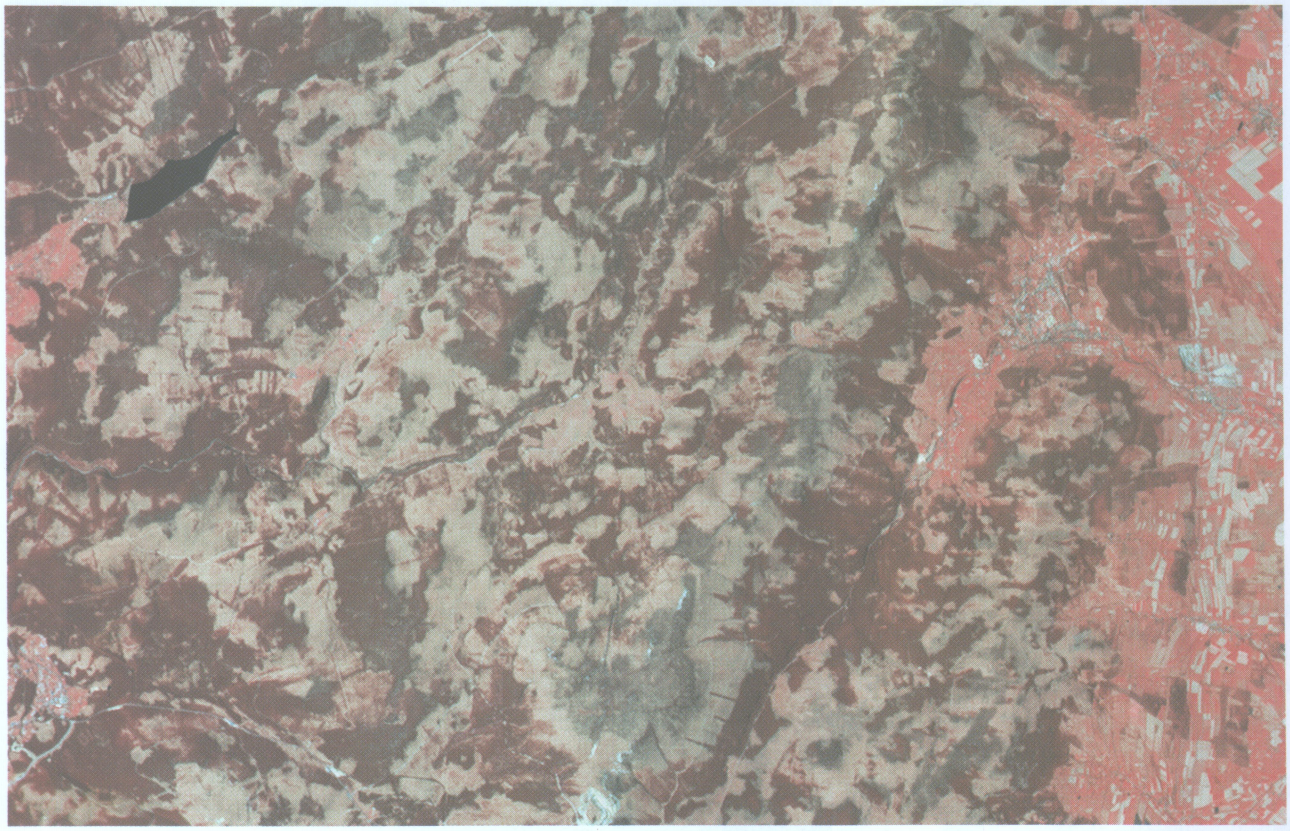
Important applications of SPOT imagery lie within the areas of forestry, agriculture, mineral exploration, local and regional planning, environmental control, navigation, mapping, the localization of industrial development etc. One important application today is the production of maps for developing countries. A valuable feature of the SPOT satellite is the possibility to register stereo imagery which can be used to produce terrain models and contours with good accuracy which means that the data can be used for the production of topographic maps. The co-operation between the company SSC Satellitbild and the National Land Survey of Sweden with the project TOPSAT, gives a unique capacity in the field of map development and production.

Practically all remote sensing satellites are served through establishments situated in or close to the town of Kiruna, north of the Arctic circle. Data are received from the polar satellites SPOT, Landsat (USA), MOS (Japan) and ERS (from 1991). Data are handled and processed at SSC Satellitbild which has excellent production resources.

From an industrial point of view, remote sensing also mirrors the profile of Swedish industry: on-board data handling, transfer of large data quantities, microwave technique, radar technique etc.

The weather satellites represent another facet of remote sensing. The Swedish Meteorological and Hydrological Institute (SMHI) has significantly contributed to the development of forecasting services by using and processing data from both polar and geostationary weather satellites. A new advanced system for data reception and image processing has been developed by SMHI, with the company Ericsson Radar Electronics as the main contractor.

Sweden's investment in remote sensing fields has also contributed to the development of a Swedish industry within computerized image processing.



SPOT-image of an area in south Poland. The light grey fields represent clear-felled areas and the dark grey fields areas of dead wood. (CNES © SPOT® Satellitbild©)

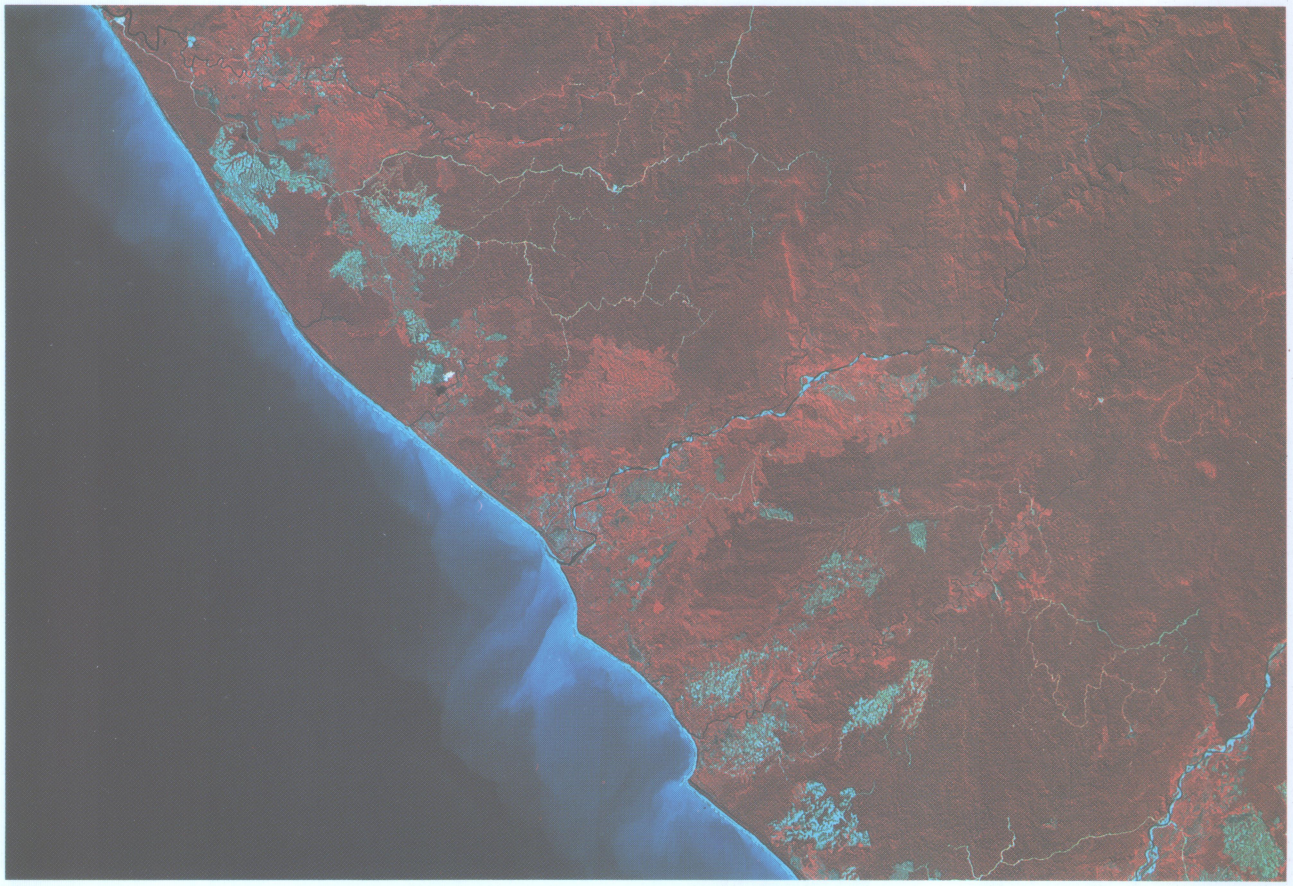
Participation in satellite projects

Sweden plans to continue to participate in the SPOT and in the ESA earth observation programmes.

In order to obtain a full return on the Swedish investments in the ERS-programme, directed towards national applications for i.a. sea surveillance, a well-prepared experimental activity is necessary. Such preparatory activities have been carried out for many years. The main emphasis is focused on the study of sea ice in the Baltic using radar techniques.

As a continuation of the very successful preparatory project BEPERS -88 (Bothnian Experiment in Preparation for ERS-1), ESA is planning a major project Programme for International Polar Ocean Research (PIPOR) which involves a large number of scientists from about ten countries including Sweden.

Sweden will also participate in the ERS-1 follow-on programme within ESA and in the development of the next generation of remote sensing satellites, the polar platforms.



SPOT-image of the coast of Sumatra, Indonesia. Deposition of mud can be seen along the coastline. (CNES © SPOT® Satellitbild ©)

Ground based remote sensing

During the last ten years major developments have taken place in Sweden in the area of ground based remote sensing. Development of the SODAR technique (SOnic radAR) has been particularly successful and an industrial product has existed for several years, and it has also been marketed internationally. The SODAR technique gives information on wind and scattering conditions in the lowest layers of the atmosphere and for this reason is widely used in various air pollution control systems. The DOAS-technique (Differential Optical Absorption Spectroscopy), developed at the Lund Institute of Technology for use in the area of weather radar has been equally successful. The DOAS-technique which makes possible the measurement and registration of a number of air pollutants in gas form has been commercialized by the company Opsis AB in Lund. A modern digital weather radar which is also capable of wind measurments with doppler technique has been developed by Ericsson Radar Electronics. This radar has been internationally marketed and is used operationally by SMHI.

Industrial development and research is in progress to develop a system for ground based microwave radiometry for atmospheric soundings up to an altitude of about 10 km. Other systems under development are vertically sounding VHF-radar for wind information in the troposphere and the stratosphere and the LIDAR-technique (Light Detection and Ranging) for laser remote sensing of the atmosphere.

Ground based systems have quickly found applications within environmental protection and operative applications within meteorology and atmosphere science. Such systems have quickly been industrialized and successfully marketed.

Peace satellites

One important application of remote sensing is the use of satellites for arms control verification and surveillance of crisis areas.

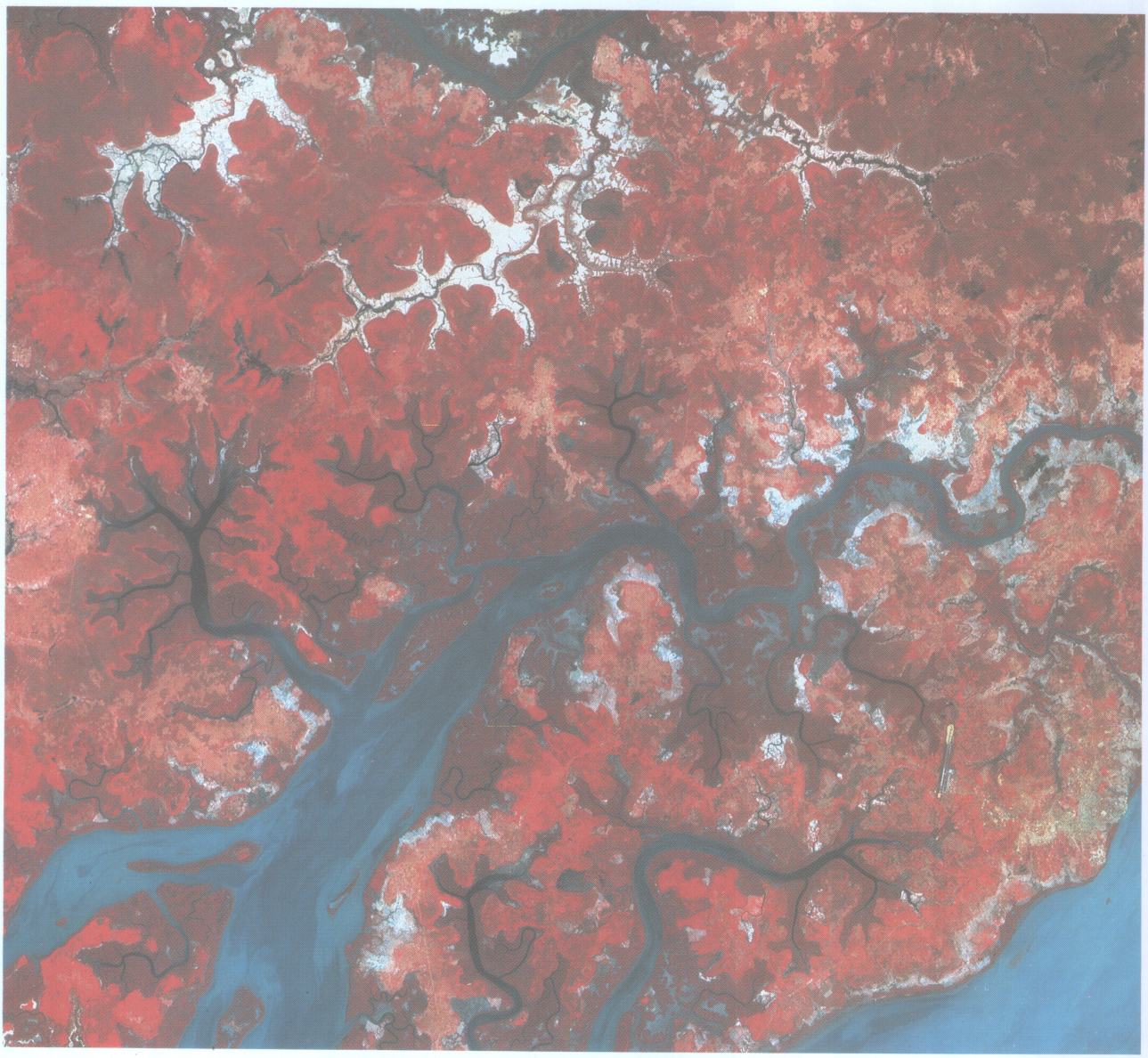
Commissioned by the Ministry for Foreign Affairs and SNSB, the SSC — in co-operation with the Defence Staff and the National Defence Research Institute — in 1988 carried out a technical study of a satellite system for verification, called "Project Tellus".

The objectives of the study were to analyse the performance, cost and capability of a satellite system for verification as a basis for discussions in international organizations, bilateral contacts and for political decisions in Sweden.

In the study, the satellite system is conceived as a component in a system for verificaion of agreements of disarmament and other confidence and security building measures, particularly in Europe.

The study was oriented towards a broad analysis of verification from space by means of optical methods. A radar alternative was also studied.

The proposed system consists of one or more satellites with the corresponding ground facility for telemetry, tracking, tele-command etc. As the satellite orbit would be more or less polar, the facility could suitably be located at a high latitude, e.g. in Kiruna where such facilities already exist.



SPOT-image over Guinea-Bissau, West Africa. The different shades of red are different types of vegetation, the dark-red being mangrove swamps. (CNES © SPOT® Satellitbild ©)

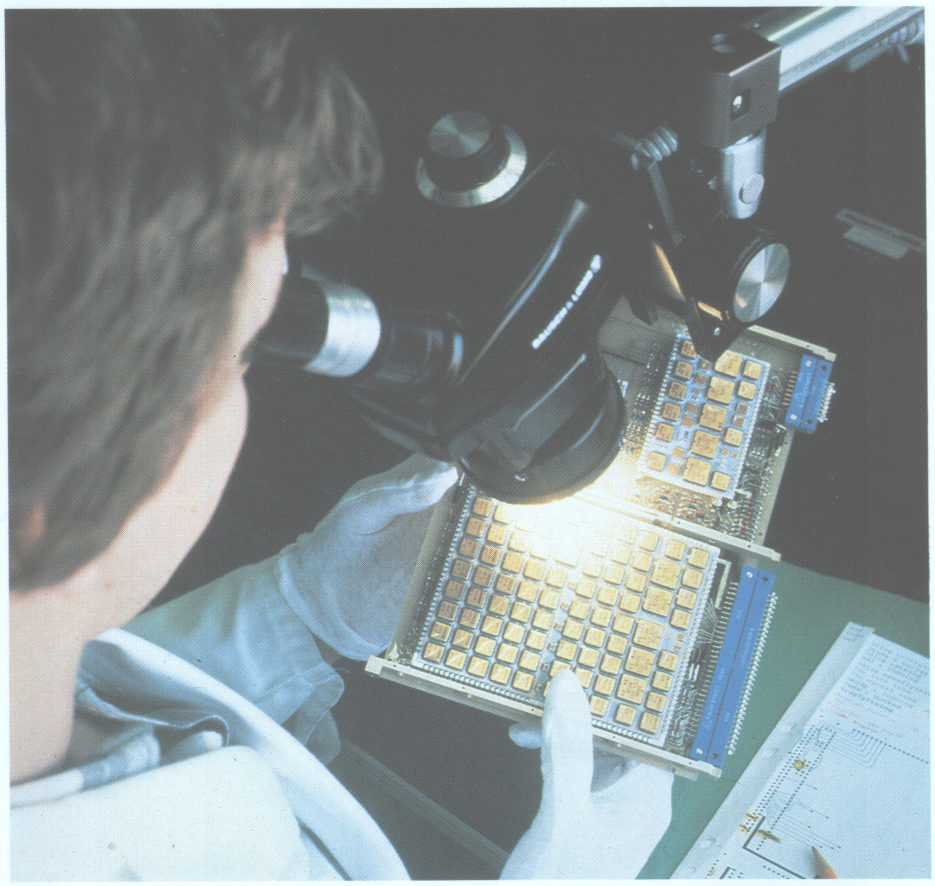
Much of the technology and methodology that today exists in civil ground segments, such as for the SPOT satellites, can be utilized for a satellite project for verification. There is no need for substantial changes to the system's structure. The ground segment can, therefore, consist of a receiving station and a facility for processing and archiving image data. It should be noted that Esrange and SSC Satellitbild respectively, both located in Kiruna, already have these functions for the SPOT project.

The study was presented to the Minister for Foreign Affairs in September 1988.

4.3 Industrial development

A major goal of space activities is to contribute to long term development of the Swedish space industry. Efforts made in the field of science and applications within the space programme also have beneficial effects on the development of industrial competence.

National and ESA contracts placed with Swedish industry increase its technical competence and industrial competitiveness. The space industry, which thus has a high-level technological research potential, is used as a fore-runner and stimulus to other industry. It is working in close collaboration with high-tech industry abroad and promotes international co-operation.



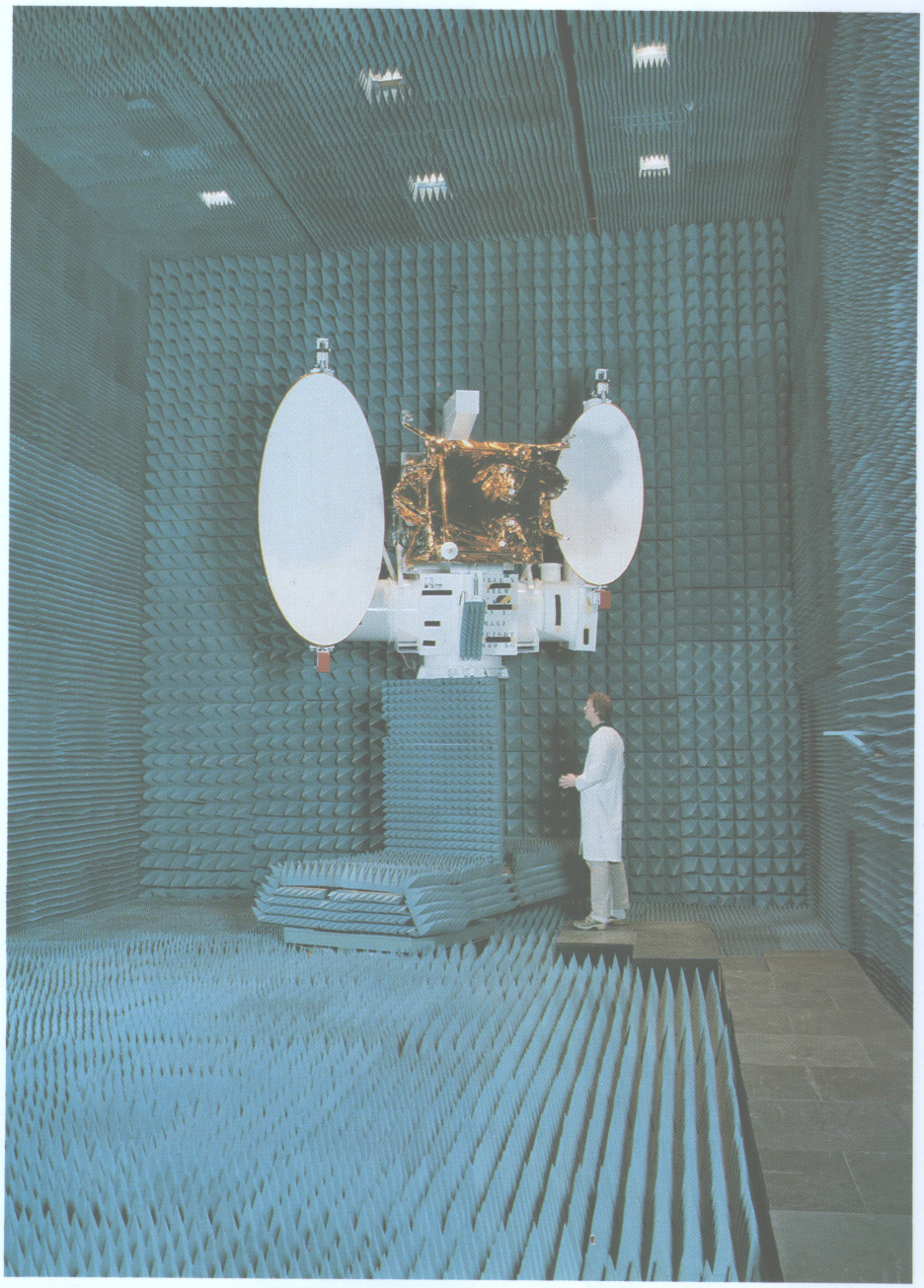
Printed circuit cards for satellite computors are being checked under microscope. (Photo Saab Space AB)

Technical development for the national programme

The national programme is based on conditions specific for Sweden: a well-developed space industry, excellent conditions for magnetospheric and ionospheric research, 20 years' experience of sounding rocket techniques and of operational space activity such as remote sensing in Kiruna.

The application area for sounding-rockets has been expanded during the last decade to include both classical space research and experiments in microgravity. The sounding-rocket techniques needed for microgravity experiments and launching to high altitudes are based on experience gained by SSC at Esrange. Of special interest in this context is the possibility of establishing the technique for microgravity experiments using Long Duration Sounding Rockets (LDSR). With such a technique it will be possible to launch payloads of 500 kg to an altitude of 1 000 km. This will allow microgravity conditions for 13—15 minutes compared to the 6—7 minutes possible today. An attitude control system (SPINRAC) for high altitude rockets is being developed by the Saab Space company.

Technical development for this type of activity is carried out both by the established space industry and by smaller companies which can offer cost-effective solutions in cooperation with SSC. Sounding-rocket techniques are in many cases a very suitable area of activity for smaller companies, since there is not the same need for special facilities and methods as for other areas of space activities.



The antennas of the DBS satellite Tele-X during synthetical near-field testing in the Ericsson-ESA test facility in Mölndal. (Photo: Ericsson Radar Electronics AB)

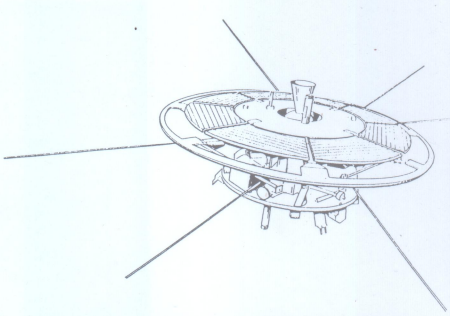
This is to a large extent true also for the Swedish model of small, low-cost, scientific satellites of the Viking type.

The scientific projects often set new technical requirements for satellite technology development. This has led to an established division of roles between ESA's scientific programme and the national basic research programmes and implies that ESA takes on the responsibility for costly and time-consuming projects.

It is thus very important that the low-cost profile represented by the Viking satellite can be developed alongside the very expensive projects of ESA and of the large space-faring nations.

Development of small, low-cost satellites is a suitable working area for Swedish space companies and can also be seen as a gateway to space activities for smaller companies.

As a step in this development, a decision has been taken to embark on the next scientific satellite project, Freja, which is planned to be launched in 1992. (Mission: See chapter 4.1)

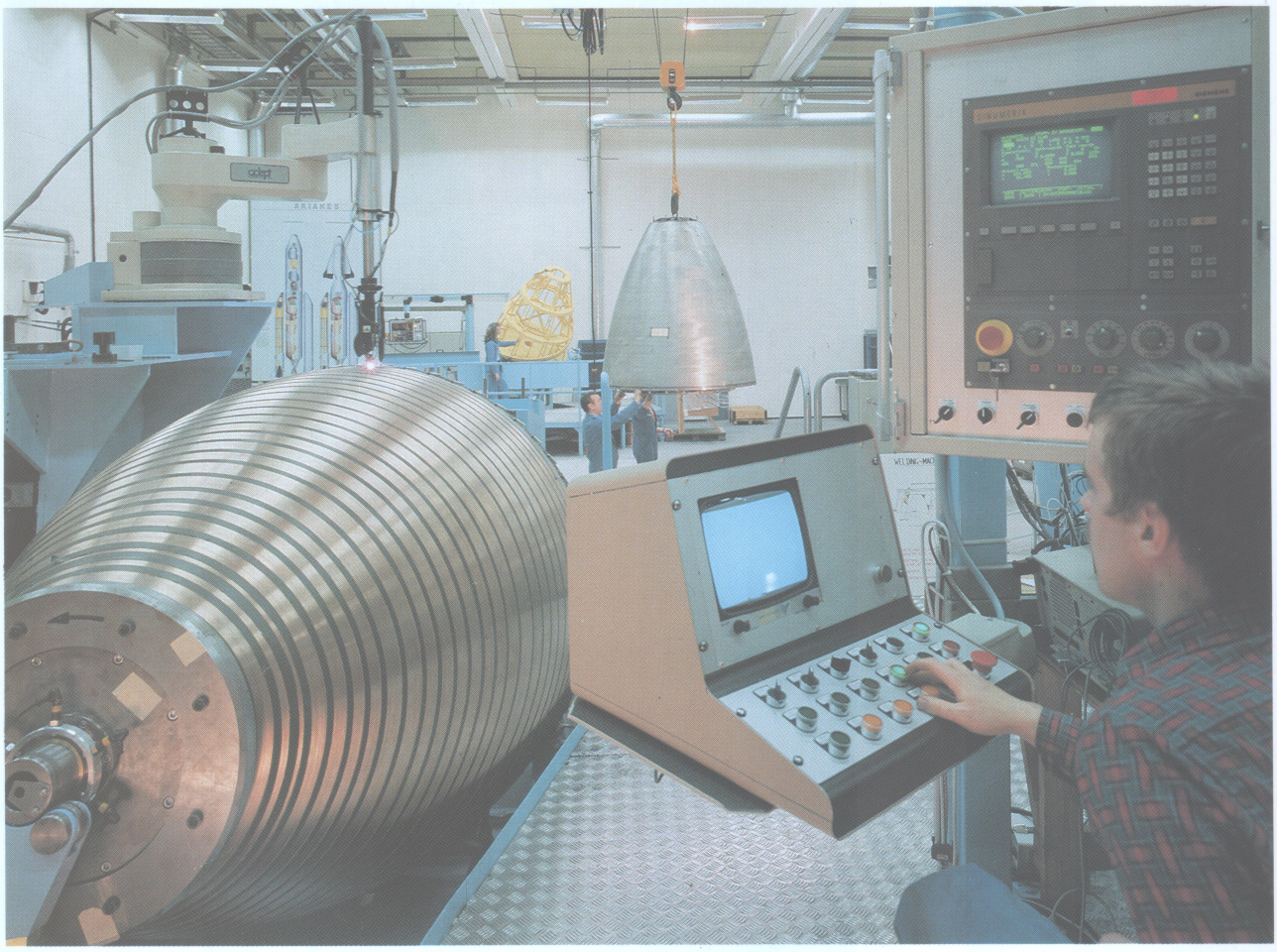


Outline drawing of the Freja scientific satellite. (FFV Aerotech)

Long-term build up of industrial competence

In 1987 the State (SNSB) and the three big space industries Saab Space AB, Ericsson Radar Electronics AB and Volvo Flygmotor AB concluded an agreement on a jointly financed industrial programme with the aim of supporting projects leading to long-term build-up of know-how in certain vital areas, and product development for future commercially interesting key areas.

This agreement came to an end during 1990 but the long-term build-up of industrial competence supported by SNSB continues.



Automatic welding of an Ariane 5 launcher nozzle. (Photo: Volvo Flygmotor AB)

The orientation of the activities within *Saab Space AB* is geared to electronics development, especially highly reliable computers on board spacecraft (OBC). The most well-known computer is the one used on board the Ariane launcher which provides signals to the guidance and navigation system, computes the necessary corrections, initiates the separation sequences of the three rocket stages and the satellite, etc. Saab Space has supplied OBC's to all Ariane launchers since the first firing in 1979.

Where the dependability requirements are very high, such as in long-term missions, the computer is usually equipped with fault tolerance functions. Fault tolerance means that the computer with a high degree of probability (over 99%) automatically detects and corrects physical, informational and design errors, thereby ensuring continuity of operations.

Saab Space has utilized its experience in the TTC and OBC fields in the development of general systems for On-Board Data Handling (OBDH).

Another field of Saab Space capabilities is the design and manufacture of sounding-rocket equipment and payloads.

Scientists' needs for higher apogee altitudes in combination with restricted impact areas, has resulted in the development of the Saab S 19 Boost Guidance System and the SPINRAC system.

Saab Space also manufactures microgravity experiment modules for the MASER Sounding-Rocket Programme.

Ericsson Radar Electronics AB in Mölndal has been active in space tecnology since the middle of the 1960's.

The space activities focus on ESA programmes for research and development and commercial satellite communications projects for organizations like INTELSAT, INMARSAT and EUTELSAT.

In communications Ericsson is mainly active in the microwave-frequency range. In the field of remote sensing Ericsson benefits from vast experience of national radar systems in designing spaceborne SAR's (Synthetic Aperture Radar).

The product fields in which Ericsson has developed special knowledge and experience are antennas, microwave equipment (receivers, oscillators, up- and downconverters) and fibre optic systems.

Ericsson developed the antenna for the ESA Giotto spacecraft which encountered the Halley Comet in 1986.

The capabilities of *Volvo Flygmotor AB* in the field of space technology are based on experience from military and commercial jet engine development.

Volvo Flygmotor has participated in the Ariane project since the beginning of the 70's and is producing combustion chambers and nozzles for the Viking engines of the Ariane launch vehicle. Volvo Flygmotor is also engaged in the technical development of future Ariane engines. The development work is based on close cooperation with SEP of France and MBB of Germany.

Volvo Flygmotor's space technology operations cover four general areas:

— Project management — such as responsibility for defining development programmes — and test management for the products manufactured by the company.

— Systems analysis of rockets and rocket engines.

— Development of engine components and sub-systems, such as turbines and the nozzle extension for the Ariane 5 cryogenic rocket engine.

— Research programmes.

A survey of Swedish space industries is found in Annex III.

The launching of a balloon at Esrange. (Photo: Esrange)

5. SPACE ACTIVITIES IN KIRUNA

Space activities in Kiruna have been presented in the various chapters of this document. The aim of the following is to give an overview of the activities, given their importance not only for the space sector as such but also as components in a national policy for regional development.

The Swedish Institute of Space Physics (IRF) has been working in Kiruna since 1957 and has now departments in Uppsala, Umeå and Lycksele. The Institute employs about 65 persons in Kiruna and is the largest recipient of funds from SNSB's national space research programme.

Esrange, the space research range situated north of the Arctic Circle at a latitude of about 68° N, was established in the middle of the 60's by ESA's predecessor ESRO as a launching site for sounding-rockets. Since 1972 the SSC has been responsible for the operation of the base. Activities are carried out as an ESA special project with the Federal Republic of Germany, France, Switzerland, Norway and Sweden as participating states.

Due to the geographical location, studies of the aurora and other high latitude phenomena are of particular interest.

The land recovery possibility makes Esrange very suitable for all sounding-rocket experiments needing recovery, for instance for microgravity research. Experiments are normally recovered within an hour from launch.

Esrange has the capacity to launch most types of sounding-rockets including high performance vehicles. Six permanent launchers make the launching of most types of sounding-rockets possible, for example Nike, Terrier and Taurus combinations, Black Brant, Skua, Petrel, Skylark and Aries. Using a guidance system it is possible to launch rockets at Esrange to altitudes of more than 500 km. A new attitude control system (SPINRAC) is being developed for rockets reaching altitudes of 800—1 000 km. The range also has long experience of releasing scientific balloons.

Esrange is also used in various satellite projects. A number of ground segments for the support of national and international spacecraft programmes are today in operation or under development.

A facility for the reception, recording, filing, processing and dissemination of remote sensing satellite data was established at Esrange in 1978. This station was originally used for spacecraft in the Landsat series and operated within the framework of the European Space Agency's Earthnet programme. The station has been extended to handle data from both remote sensing and scientific satellites and has several independent antennas and processing systems.

A satellite control station of universal design performs TT&C operations on orbiting satellites. Esrange operates and monitors satellites on behalf of customers or offers use of the station in a transparent mode where remote customers are connected to the station for real time access to their satellites.

The ground control station for the Swedish telecom and DBS satellite Tele-X, is also located at Esrange.

About 100 persons are employed at Esrange.

At Salmijärvi, in the vicinity of Esrange, ESA has established a ground station for ERS-1, which is operated by SSC.

As a result of the French-Swedish cooperation, the company SSC Satellitbild has been established in Kiruna as a subsidiary to SSC. SSC Satellitbild has a staff of fifty.

6. SWEDEN AND ESA

As was pointed out in chapter 3 the main part of the Swedish space activities is performed in international cooperation within ESA. Chapter 3 also gives the general background and figures for the Swedish ESA participation.

In November 1987 the Council of the European Space Agency, meeting at ministerial level in the Hague, laid down the main policy guide-lines for European space development up to and beyond the year 2000. The goals of the space policy decided upon were translated into a concrete long term plan which will place Europe in the front line for the peaceful exploration and use of outer space and enhance Europe's autonomous space capability, including manned activities.

With a view to guaranteeing the future scientific programme (mandatory), "Horizon 2000", the Ministers decided on a continued yearly budgetary expansion of 5% until 1992.

The objectives of the programme "Horizon 2000" are to contribute to the advancement of fundamental scientific knowledge, establish Europe as a major participant in the worldwide development of space science, offer a balanced distribution of opportunities for frontline research to the European scientific community and provide major technological challenges for innovative industrial developments.

"Horizon 2000" consists of four corner-stones balanced by smaller, flexible projects. A go-ahead has been given for the first corner-stone, the Solar-Terrestrial Science Programme (STSP) which contains two missions: a four-spacecraft space-plasma-physics mission, named Cluster and which is of particular interest to Swedish scientists and a second one, named SOHO (the Solar and Heliospheric Observatory).

A go-ahead has also been given to the second cornerstone XMM, which is an X-ray astronomy mission containing a major project aimed at studying X-ray sources with

Launch of Ariane 4 from the Space Centre in Kourou, French Guyana. (Photo ESA)

good spectral resolution. Further, there are a planetary corner-stone (Rosetta) comprising a major project to visit primitive bodies of the solar system and to return pristine material from a comet, and a sub-millimetre astronomy corner-stone (FIRST) comprising a large telescope for studies of the physical characteristics of infrared sources by means of heterodyne detectors.

The long term plan decided upon in the Hague also implied the starting of three large infrastructure programmes: the Ariane 5 Launcher, the space plane Hermes and the space station and platforms programme Columbus.

The ESA member states and Canada have decided to participate in the three major programmes at levels which are shown in the following table (situation mid 1990)

As can be seen from the table, Sweden now participates in all of the large infrastructure programmes.

States	Ariane 5 (%)	Columbus (%)	Hermes (%)
Austria	0.4	—	0.5
Belgium	6.0	5.0	5.8
Denmark	0.5	1.0	0.45
France	44.7	13.8	43.5
FRG	22.0	38.0	27.0
Ireland	0.2	—	—
Italy	15.0	25.0	12.1
Netherlands	2.3	1.3	2.2
Norway	0.4	0.4	0.2
Spain	3.0	6.0	4.5
Sweden	2.0	1.0	1.3
Switzerland	2.0	—	2.0
United Kingdom	—	5.5	—
Canada	—	—	0.45

In order to improve the industrial return of Sweden's ESA participation — both in terms of quality and quantity — Swedish policy is to retain and strengthen the levels of participation in those space application programmes where there are good prospects for developing the specific national competence that has been built-up as a result of the efforts made during the 70's and the beginning of the 80's.

Sweden has participated in the development of all the generations of the Ariane launcher and is also participating in the next generation, Ariane 5. Industries involved here are Saab Space AB (on-board computers) and Volvo Flygmotor AB (turbines and nozzles).

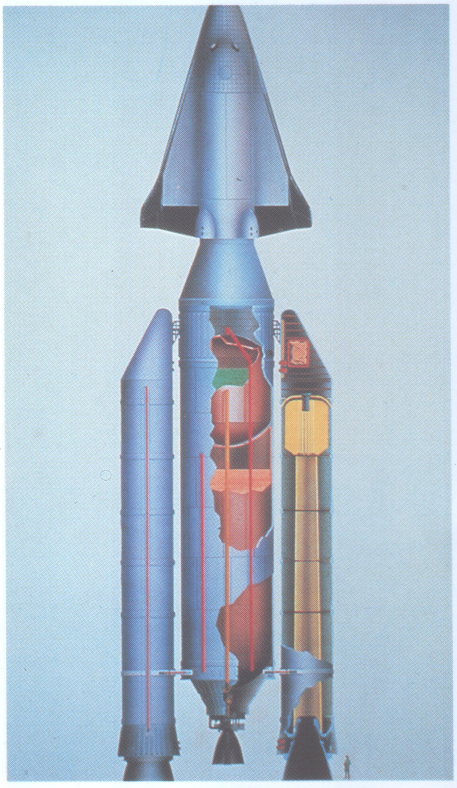
Within the ESA telecommunication programme, the programmes for experimental telecommunications (PSDE), a technology demonstration mission (TM), and data relay satellites (DRS), are of special interest to Swedish industry, primarily Ericsson Radar Electronics AB, with regard to the possibilities they contain for development of electronics and antennas.

Participation in the earth observation programme is of particular interest because of its inherent potential for Sweden with regard to the activities in Kiruna and the competence already acquired in the French-Swedish SPOT-cooperation.

The communication and earth observation satellite programmes also serve user organizations, such as EUTELSAT and EUMETSAT.

ESA's microgravity programme comprises material science, crystallisation for development of semiconductors, crystallisation of proteins, plant physics, cell biology and physiological research. Sweden participates in several projects. The programme is of particular national interest with regard to the sounding-rocket facilities available at Esrange (Kiruna).

The level of Sweden's overall ESA participation compared to the GNI-level is shown in Figure 4.



Ariane 5 and Hermes. (Picture: ESA)

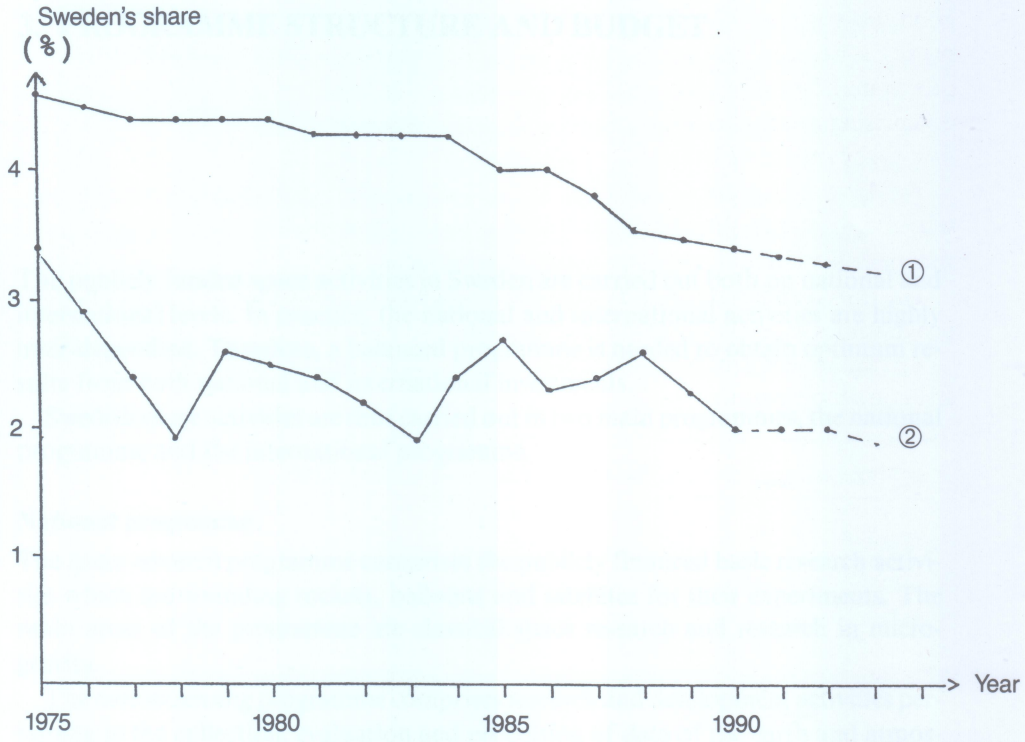


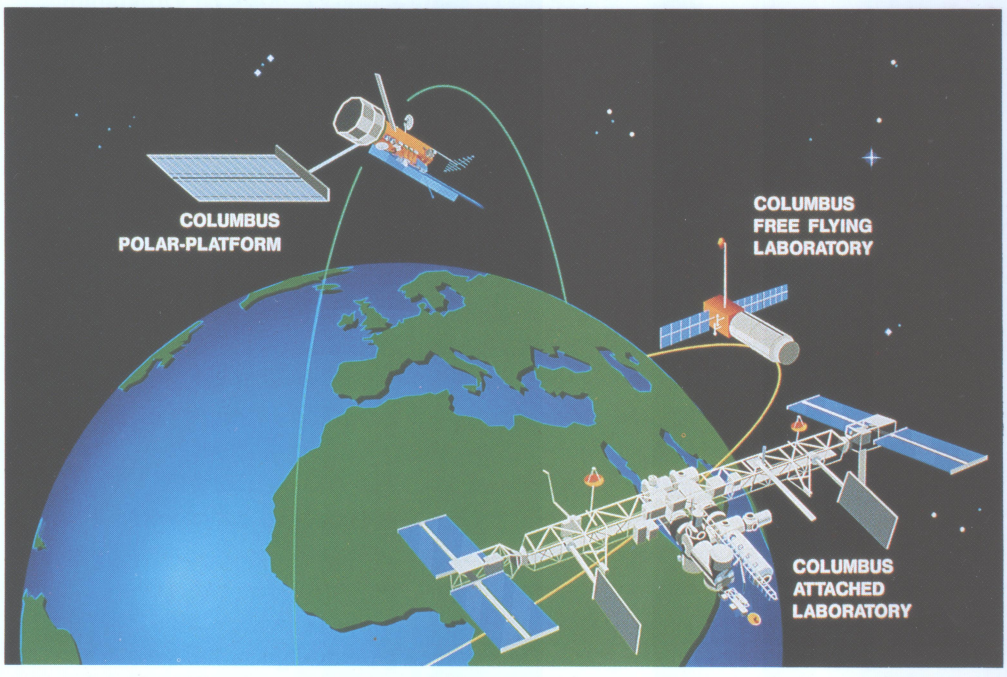
Fig 4. Sweden's share of the ESA programmes

① Sweden's GNI-level (3,5% 1990)) ② Sweden's share of the ESA programmes

The line showing participation according to GNI, represents an ideal state of affairs and should be seen as a long term goal.

In 1989/90, which is the reference year, the overall Swedish participation level in ESA optional programmes amounts to about 1,9%. The average figure for the level of Swedish participation in all ESA programmes can be estimated to 2,3%.

When dealing with relative shares of ESA participation, one should keep in mind the vigorous expansion of the ESA programmes and budgets. What is shown as a relative decrease in Sweden's ESA participation still represents an increase of Sweden's space budget in absolute terms. (compare fig 3)



The Columbus programme — polar platform, freeflying laboratory and attached laboratory. (Picture: ESA)

SWEDISH SPACE CORPORATION

Swedish Space Corporation (SSC)
P O Box 4207
S-171 04 Solna
Tel: +46 8 627 62 00
Telex: 17128 SPACECO S
Fax: +46 8 98 70 69

Fields of activity:

The Swedish Space Corporation, SSC, is a government-owned limited company under the Ministry of Industry, with activities covering the entire range of space-related work from feasibility studies to operational applications of space technology. Systems engineering and management are typical of the company's activities, but SSC also designs and develops high-technology hardware in-house, especially for use in space vehicles and in satellite ground stations. SSC also offers a complete remote sensing programme. SSC has a long and successful tradition of international cooperation in all areas of its business.

The total number of employees is 280

ESRANGE (SSC's satellite operations facility and sounding rocket range)

SSC Esrange
P O Box 802
S-981 28 Kiruna
Tel: +46 980 720 00
Telex: 8744 ESRANGE S
Fax: +46 980 213 31

Fields of activity:

Performs TT&C operations on orbiting satellites. Esrange operates and monitors satellites on behalf of customers or offers use of the station in a transparent mode where a remote customer is connected to the station for real time access to a satellite.

Handles most types of high performance sounding rockets. The latest development, MAXUS, flies to a maximum altitude of 900 km and gives 14 minutes microgravity with a 600 kg payload.

Balloon payloads up to 500 kg can be flown from Esrange to altitudes above 40 km.

Receives data from remote sensing satellites.

SSC Satellitbild (a subsidiary of SSC)

Satellitbild i Kiruna AB
P O Box 816
S-981 28 Kiruna
Tel: +46 980 121 40
Telex: 8761 SATIMA S
Fax +46 980 160 44

Fields of activity:

Processes and refines satellite data into a variety of customer products. All steps — standard processing, geocoding, extraction of elevation data from stereo pairs, analysis and production of topographic and thematic maps — are carried out in an integrated production chain.

SWEDISH RESEARCH GROUPS

The scientific activities of the Swedish research groups are mainly:

Magnetospheric and ionospheric physics, in particular measurements of charged particles and electric and magnetic fields using satellites, sounding rockets and balloons.

Groups: — Swedish Institute of Space Physics, Kiruna
— Swedish Institute of Space Physics, Uppsala
— Dept of Plasma Physics, The Royal Institute of Technology, Stockholm

Upper atmosphere studies, (80—150 km) in particular atmospheric processes and composition at high latitudes using sounding rockets.

Group: — Dept of Meteorology, University of Stockholm

Astrophysics and astrometry, in particular studies of solar and stellar UV radiation, IR studies and astrometry using satellites, sounding rockets and ballons

Groups: — Lund Observatory, University of Lund
— Stockholm Observatory, University of Stockholm
— Uppsala Astronomical Observatory, University of Uppsala
— Onsala Space Observatory, Chalmers University of Technology, Gothenburg

Material sciences, in particular solidification of metals, diffusion processes in liquid metals and crystal growth in microgravity using sounding rockets.

Group: — Dept of Casting of Metals, The Royal Institute of Technology, Stockholm

Life sciences, in particular studies of human physiological processes in microgravity.

Group: — Dept of Baromedicine, Karolinska Institutet, Stockholm

Biophysics, in particular electrophoretic and protein crystal growth studies in microgravity.

Group: — Dept of Physical and Inorganic Chemistry, Chalmers University of Technology, Gothenburg.

Remote sensing, in particular microwave radiometry, spectral signatures and image analysis using satellite images registered by airborne or land-based sensors.

Groups: — Dept of Radio- and Space Science, Chalmers University of Technology, Gothenburg
— Remote Sensing Laboratory, Dept of Physical Geography, University of Stockholm
— Remote Sensing Laboratory, Dept of Physical Geography, University of Lund
— Dept of Physics, Lund Institute of Technology
— Remote Sensing Laboratory, Swedish University of Agricultural Sciences

(Note: several groups are engaged in research concerning remote sensing; only the largest and most active groups are listed here.)

See "Space Research in Sweden" published biannually in connection with the COSPAR-meetings.

SAAB-SCANIA AND ERICSSON IN SPACE JOINT-VENTURE

Saab Scania and Ericsson have merged their space activities, by joining Saab Space with the space activities within Ericsson Radar Electronics AB.

The new company, SAAB ERICSSON SPACE AB started on January 1, 1992.

SAAB ERICSSON SPACE AB
S-405 15 GÖTEBORG

Tel: +46 31 350000

Fax: +46 31 359609

Telex 27950 saabsp s

Fields of activity: See opposite page
Number employed: about 360

SWEDISH SPACE INDUSTRIES

Three major Swedish industrial concerns, Saab-Scania, Volvo and Ericsson are engaged in space activities. The involved companies, which also perform the major part of space contracts, are

Saab Space AB (within the Saab-Combitech group)
S-405 15 Göteborg, Sweden
Tel +46 31 37 00 00
Telefax +46 31 21 08 00
Telex 27950 saabsp s

Fields of activity: spacecraft systems, computers and data handling, sensor system mechanisms, spacecraft structures, flight control systems for sounding rockets, microgravity payloads and small satellites.

About 250 people are working with space activities of which 200 are in Gothenburg and 50 in Linköping.

Ericsson Radar Electronics AB
S-431 84 Mölndal, Sweden
Tel +46 31 67 10 00
Telefax +46 31 87 66 39
Telex 20905 ericrr s

Fields of activity: microwave antennas, microwave electronics and fibre optics.

In total approximately 140 people are involved in everyday work in the space projects.

Volvo Flygmotor AB
S-461 81 Trollhättan, Sweden
Tel +46 520 940 00
Telefax +46 520 150 31 or 340 10
Telex 42040
Cable flygmotor

Fields of activity: production of combustion chambers and nozzles for Viking (Ariane 4), development of nozzle and turbine for Vulcain (Ariane 5), technology programme in pump systems, nozzles and combustion.

About 130 persons are working with space activities.

Other Swedish companies and institutes in the space field:

The Aeronautical Research Institute of Sweden (FFA)
PO Box 11021, S-161 11 Bromma, Sweden

Fields of activity: aerodynamic R&D, wind tunnel tests.

ABB Hafo AB
PO Box 520, S-175 26 Järfälla, Sweden

Fields of activity: optocouplers, ASIC (SOS4 process)

FFV Aerotech
S-732 81, Arboga, Sweden

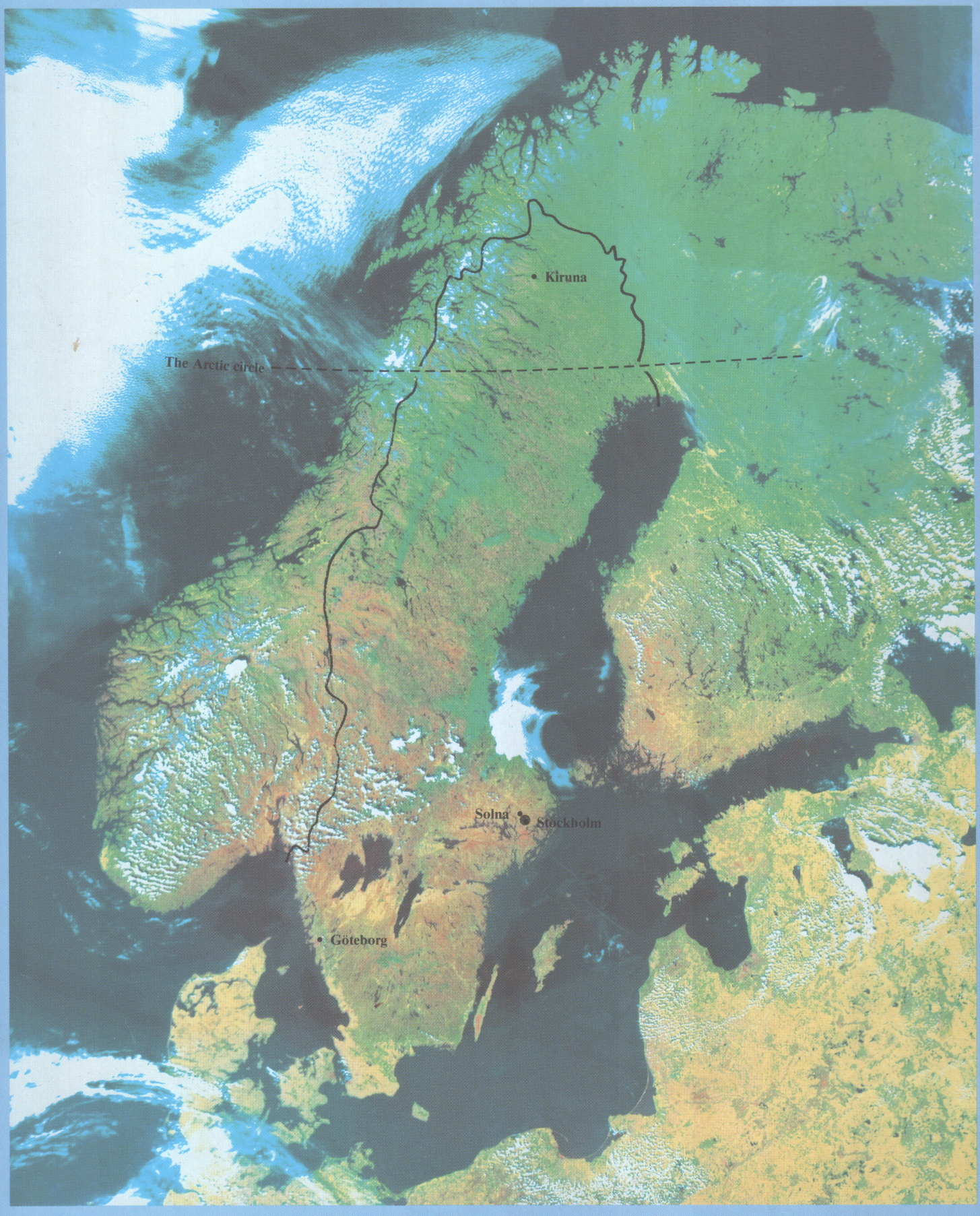
Field of activity: assembly, integration and test of small satellites (Freja).

Cepro Konsult AB
PO Box 440, S-101 25 Stockholm, Sweden

Field of activity: project management tools.

FISCAL YEAR 1989/90 BUDGET FOR THE SWEDISH NATIONAL SPACE BOARD (price level 1988)

Income		**MSEK**
Ministry of Industry		314
Ministry of Education and Cultural Affairs		88
Other income		17
		419
Expenditure		
Basic activities		73
— National (Adm., Esrange)	18	
— ESA	55	
Science (incl. micrograv.)		106
— National	35	
— ESA	71	
Remote sensing		70
— National	12	
— ESA	28	
— Bilateral (SPOT)	30	
Industrial development		170
— National	35	
— ESA	128	
— Bilateral	7	
		419
National programme	100	
International programme	319	
		419



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